A

BLAIR'S

CANADIAN DRAWING SERIES.

AUTHORISED BY THE

COUNCIL OF PUBLIC INSTRUCTION, BRITISH COLUMBIA.

BOOK 4 A, GEOMETRICAL DRAWING.

DAVID BLAIR,
Science and Art Master
Normal School, Vancouver, British Columbia

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BLAIR'S
CANADIAN DRAWING SERIES

SECOND EDITION

GEOMETRICAL DRAWING—BOOKS IV—A and V—A.

This new Edition of the Authorized Drawing Books for British Columbia has been prepared by direction of the Council of Public Instruction.

In the former Edition the Practical Geometry was given in the same book as the Freehand Drawing; and although a good deal of preliminary geometrical work is given in the first three books of this Edition, two additional books, IV—A and V—A, are now published dealing exclusively with this section of Drawing.

The changes that have been made, and the new work required may be briefly indicated as follows:—

Practical Plane Geometry. Formerly a small drawing showing the working lines of each problem appeared beside the printed stages of construction for it at the foot of the page. Instead of studying these instructions and working out the problems therefrom *assisted* by the small drawings, pupils more frequently than not ignored the instructions and copied the small drawings—in numberless cases quite incorrectly. To obviate, in a measure, this state of things all the small drawings now appear together on a separate page as the answers do in arithmetic.

A number of additional problems with exercises are given: these are principally related to Applied Science.

Practical Solid Geometery. As in Plane Geometery, the small drawings are all now together on a separate page.

Almost all the problems formerly given in Books IV and V now appear in IV—A. The new work includes elementary sections of solids; plans and elevations from a description or specification. The projection of objects requiring the use of three planes of projection.

Scale Drawing. Freehand sketching from and measuring the sizes of actual objects—drawing the same to scale. The construction of English and French Scales. Comparative Scales.

Pattern Drawing. More advanced work, as suggested by small drawings, Example 2, is now required in this section of the subject.

My thanks are due to Mr. J. Kyle, A.R.C.A., Supervisor of Drawing in the Vancouver Public Schools, for several important suggestions in connection with the work.

DAVID BLAIR,
SCIENCE AND ART MASTER

PROVINCIAL NORMAL SCHOOL,
VANCOUVER, B.C., *June, 1908.*

CONTENTS OF BOOK IV-A

NOTE—Although the work of each section is placed together, it is not intended that one is to be finished before proceeding to the next, on the contrary they may be taken in any order except of course that the problems in Plane Geometry or Solid Geometry are to be taken consecutively.

INSTRUCTIONS

On arriving at this stage pupils will, as a result of the geometrical work done in the lower classes, not only have learned a good deal about the use of the materials—pencil, ruler, measure, set-squares and compass, but they should be able to give fairly clear descriptions, oral and written, of the simple geometrical figures and the lines connected with them; namely, the circle, triangles, quadrangles, the hexagon, and the octagon, and be able to construct more or less accurately with the measure, set-squares, and compass these figures from given sizes.

PRACTICAL PLANE GEOMETRY. The work of each problem is to be taken by the teacher stage by stage on the blackboard with the class. Before beginning to draw a problem the whole construction should be gone over orally with the class, reference being made to the small drawing Example 1 representing it.

For some of the problems there are two drawings required in which the data vary as regards form, prob. 3, or position, prob. 4. Pupils should be taught to solve problems however the data may vary; moreover, they should be able to apply any of these problems to specific cases. See note, prob. 1, to find the centre of a circle, etc.

For ruling lines, the edge of a set-square is better than that of a long, narrow straight-edge. See that the letters of reference, which should be carefully drawn in, are either quite upright or all sloping at the same angle.

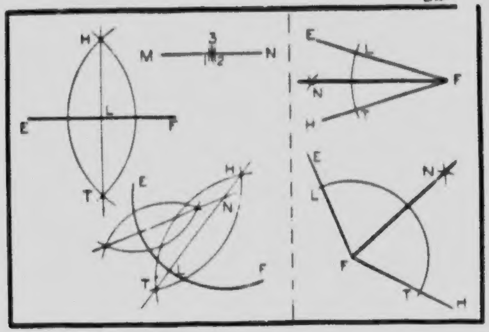
PRACTICAL SOLID GEOMETRY. Not only are the principles involved in this section of the work to be explained to the class experimentally at the beginning of the course, but each problem throughout the course is to be illustrated by the actual planes of projection in position accompanied by the solid the problem requires.

(Continued on page 3 of Cover.)

PRACTICAL PLANE GEOMETRY

Lazy folk take the most pains.

Ex-



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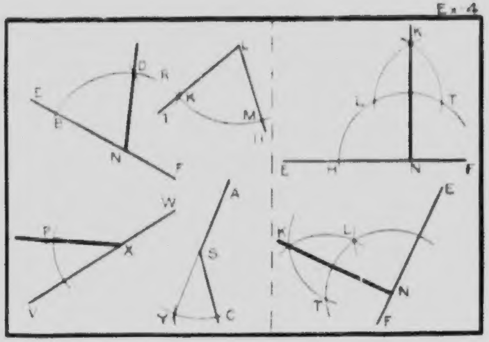

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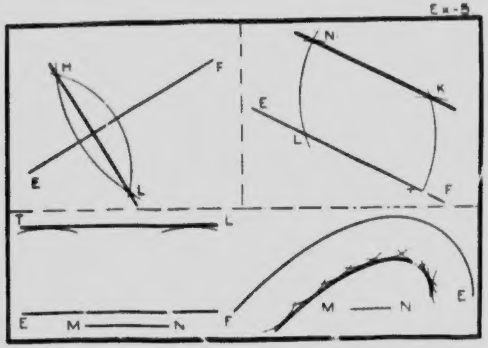

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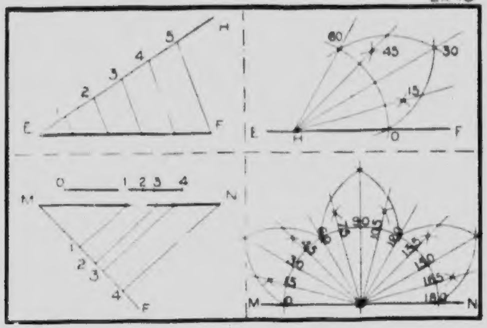

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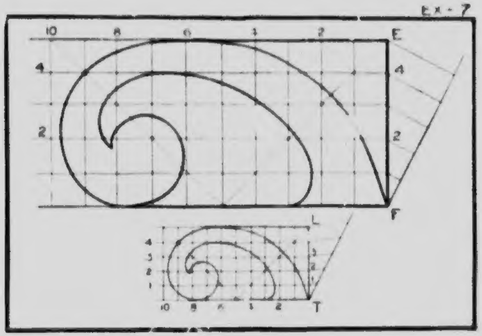

PROBLEMS IN PLANE GEOMETRY.—The above drawings show the lines required in working out the 12 problems—Examples (pages) 3 to 7 in this book. Before beginning to work a problem the pupil should read over all the stages of construction printed below the given conditions, and at the same time may refer to the lines of construction shown on these small drawings. The problem shoul then be done without further reference to this page.

The letters of reference are to be carefully drawn in on each problem as shown here.

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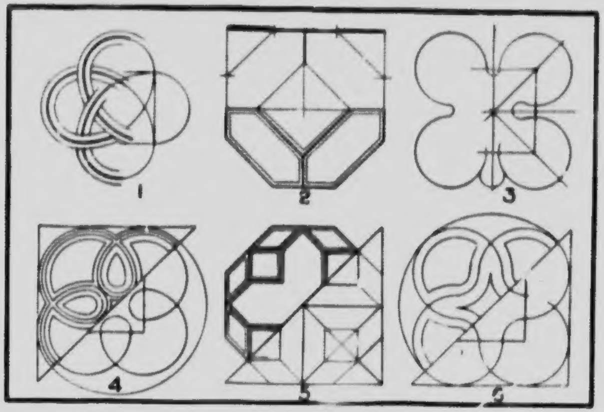
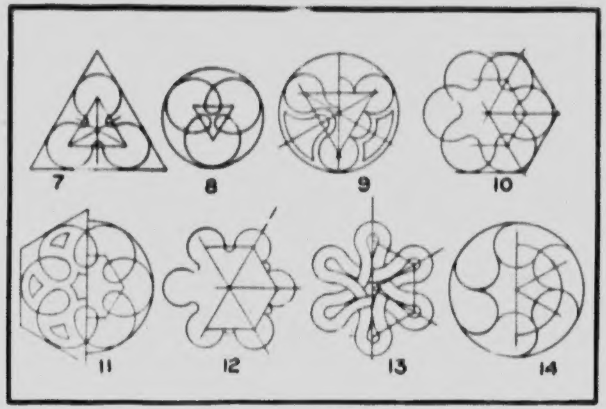
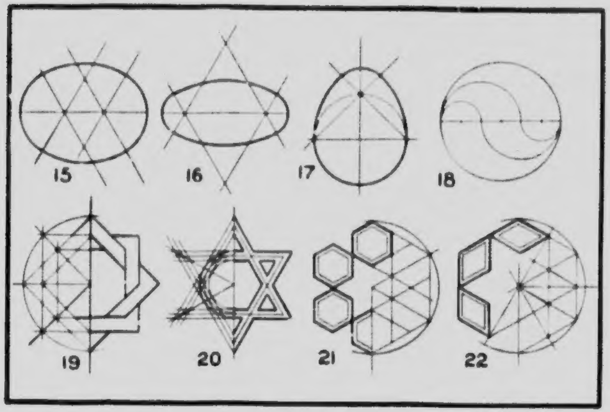
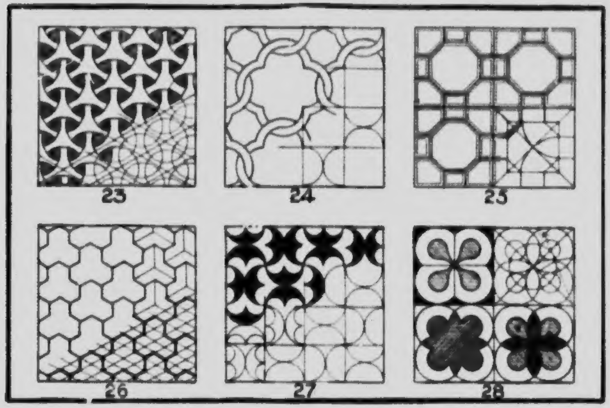
Mean to be something with all your might.

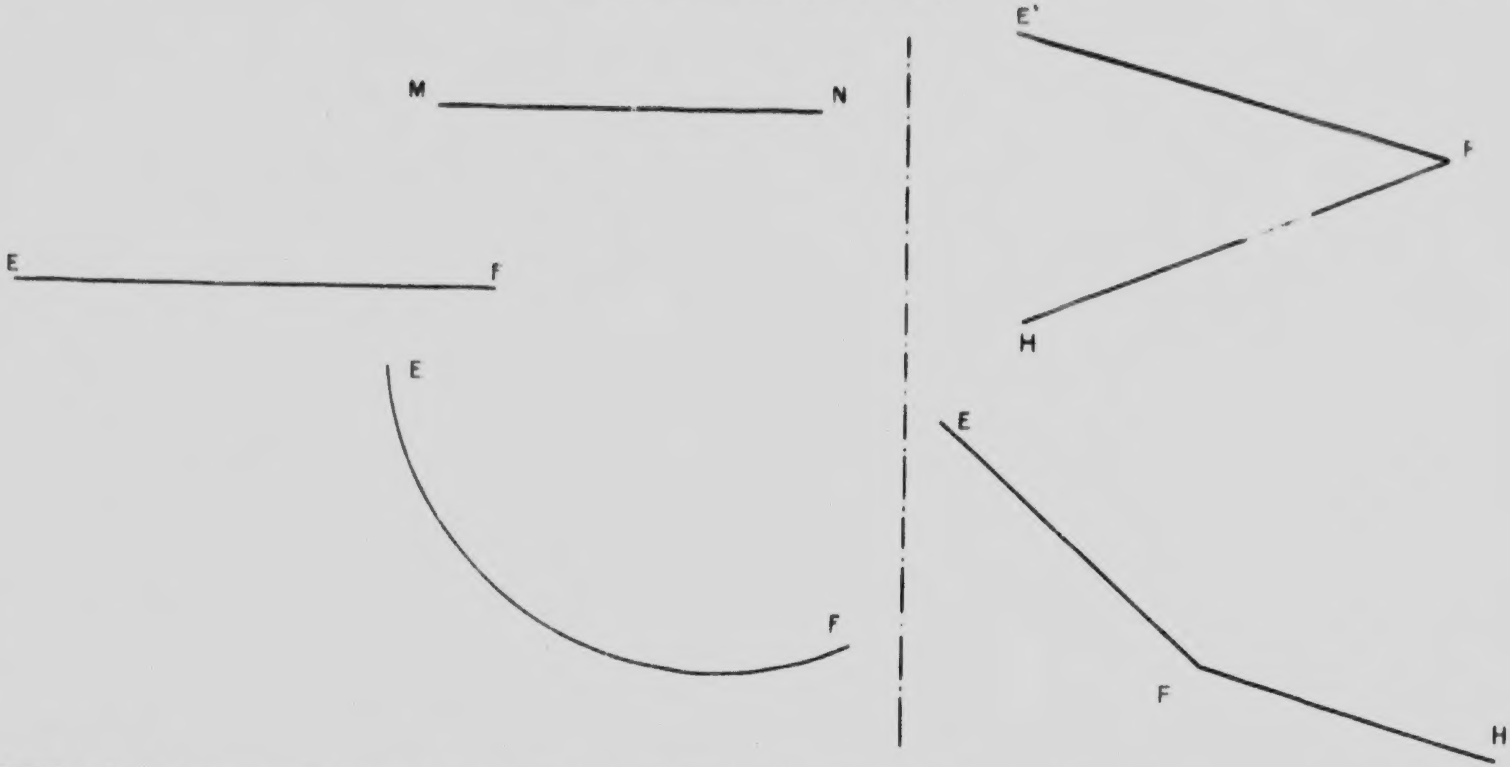








PATTERN DRAWING.—The above pattern drawings (connected with decorative design) are given as suggestions with regard to the work required o[illegible] blank pages for Examples 8 to 12. The pupil is to study the [illegible]struction lines, and select a triangle square hexagon or [illegible]gon on which an original geometrical design is to be worked out. One or two of the above drawings may be copied much larger as preliminary practice. The pupil will find explanatory notes regarding the above figures on the pages devoted to this work. After a little attentive study it will be seen that the construction of these patterns is in almost all cases exceedingly simple, and although the work of the pupil is to a certain extent manual it is mainly inventive. Two drawings are to be made on each page, and they are to be as large as the available space will admit: *small drawings are on no account to be attempted.*



PROBLEM 1.—To bisect a given straight line EF or a given arc EF; that is, to divide it into two equal parts.

1.—From **E** as centre, with any radius greater than one-half **EF**, describe an arc.

2.—From **F** as centre, with the same radius, describe another arc cutting the former one in points **H** and **T**.

3.—Through **H** and **T** draw a line cutting **EF** in point **L**; then **EL** will be equal to **FL**.

NOTE.—*The line* **HT** *is, in the case of the given straight line* **EF**, *perpendicular with it; the line* **HT** *bisecting the arc, passes through the point from which the given arc was described; and if the arc* **EL** *be bisected, its line of bisection will cut the line* **TH** *in* **N** *the actual centre from which the given arc was described. In this way* **a circle may be described about any given triangle** *(bisect any two sides), and* **the centre of a given circle may be found** *(mark any three points on the circumference and bisect the arcs).*

A line as **MN** *may be bisected by trial with compasses, thus: Mark off two equal distances* **M1** *and* **N2** *as nearly half the length of* **MN** *as can be guessed. Then the compass can be adjusted for the next trial to get* **3**, *the exact point of bisection.*

PROBLEM 2.—To bisect a given angle EFH.

1.—With any radius describe an arc from **F** cutting the lines in **L** and **T**.

2.—From **L** and **T** as centres, with a suitable radius, describe arcs intersecting at **N**.

3.—Through **N** draw a line to **F**; then the angle **EFN** will be equal to **HFN**.

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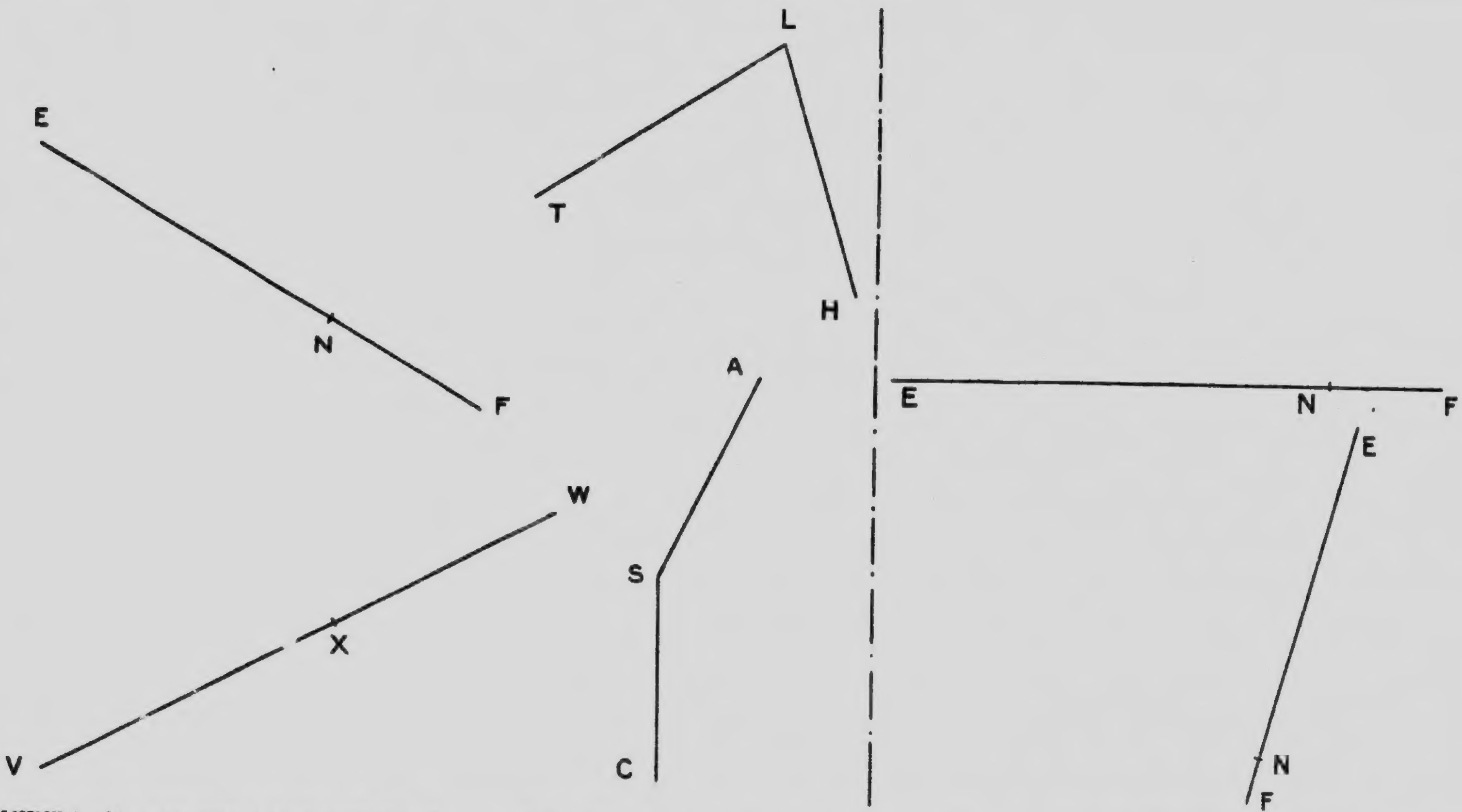


PROBLEM 3.—At a given point N in the given line EF, to make an angle equal to the given angle TLH.

1.—With centre **L** and any radius describe an arc **KM**.

2.—With centre **N** and the same radius describe an arc **BR**.

3.—With centre **B** and the distance **KM** cut off **BD**.

4.—From **N** draw a line through **D**; then the angle **DNE** will be equal to the given angle **TLH**.

NOTE.—*When the given angle as* **ASC** *is very obtuse, accuracy is more easily obtained as follows:—Produce either side of the given angle as* **AS** *to* **Y**, *forming the acute angle* **CSY**. *At the point* **X** *in the given line* **VW** *make an angle* **VXP** *equal to* **CSY**; *then* **PXW** *will be equal to* **ASC**.

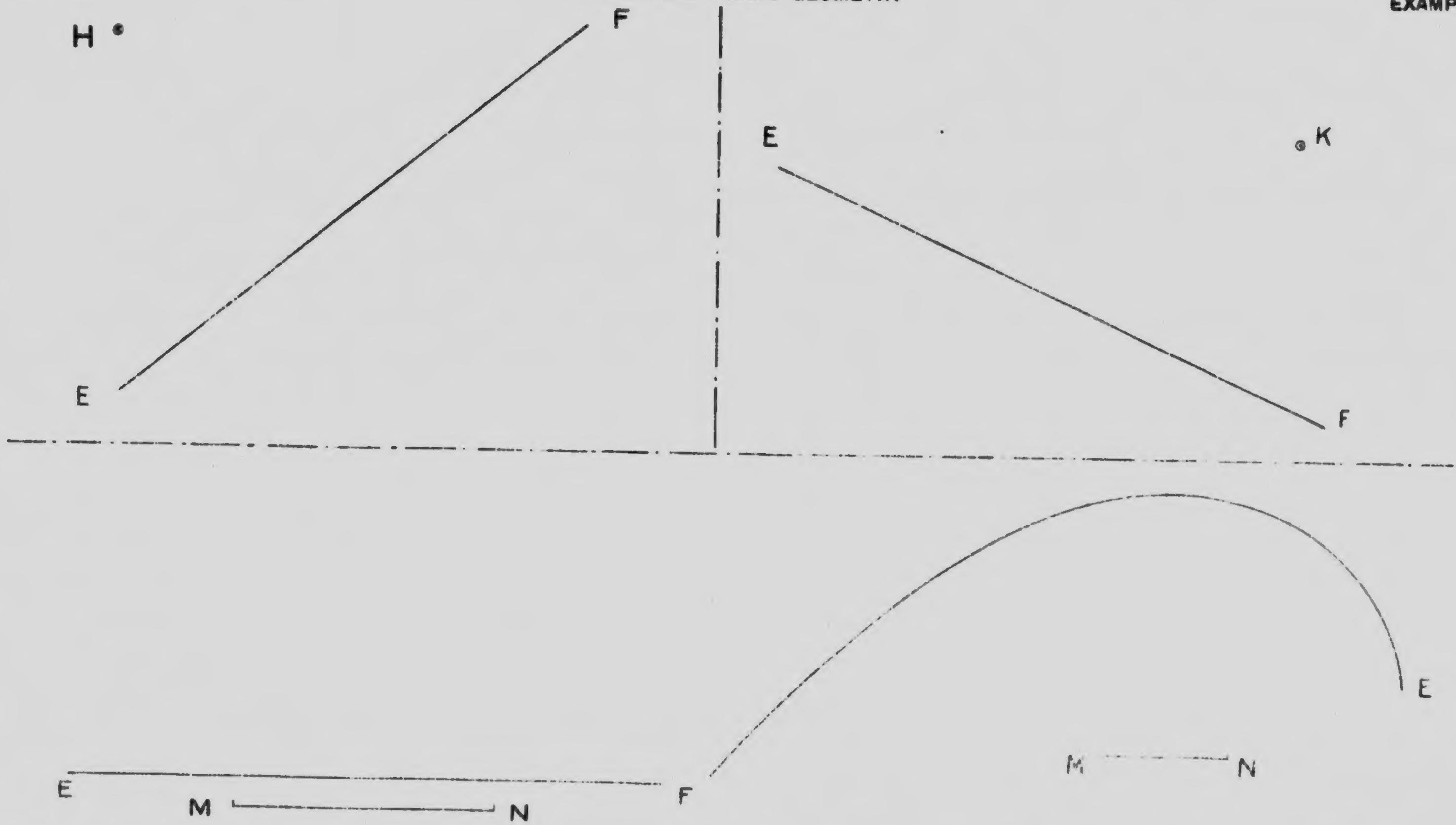
PROBLEM 4.—To draw a perpendicular from a given point N, in a given straight line EF.

1.—From centre **N**, with any radius describe a long arc cutting **EF** in **H**. (Keep the same radius till the problem is finished.)

2.—From **H** cut the arc in **L**, and from **L** cut it again in **T**.

3.—From **L** and **T** describe arcs to intersect in **K**.

4.—A line from **N** through **K** will be perpendicular with **EF**.



PROBLEM 5.—To draw a perpendicular to a given line EF from a given point H outside it.

1.—With centres **E** and **F** (or any two points on the given line), describe arcs to pass through **H**, long enough to intersect on the other side of **EF** in point **L**.

2.—A line through **H** and **L** will be perpendicular to **EF**.

PROBLEM 6.—To draw a line parallel to a given line EF, at a given distance from it equal to MN.

1.—From centres **E** and **F** (or any two points on the given lines, with the given distance **MN** as radius, describe arcs.

2.—A line **TL** touching the arcs will be the required parallel.

NOTE.—**Parallel curves** *are obtained in the same way. Take any number of points—the more the better—on the given curve, and describe arcs from these. A line drawn to touch these arcs will be parallel to the given curve.* See Problem 6, Example 1.

PROBLEM 7.—To draw a line through a given point K, parallel with a given straight line EF.

1.—From **K** with any radius, describe a long arc to cut **EF** in **L**.

2.—From **L** with the same radius, describe an arc passing through **K**, and cutting **EF** in **T**.

3.—With centre **L** and the distance **TK** cut off **LN**.

4.—A line through **K** and **N** will be the parallel required.

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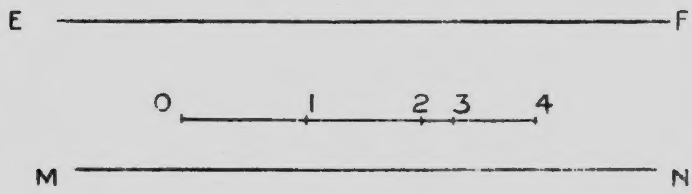
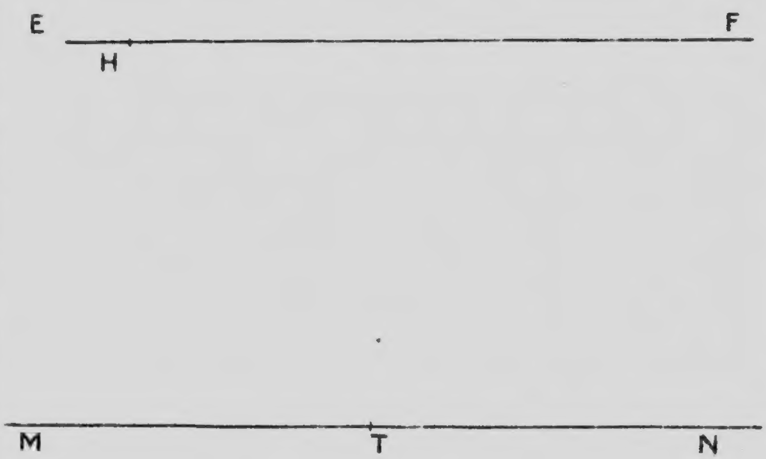




PROBLEM 8.—To divide a straight line EF into any number of equal parts, say five.

1.—From **E** draw **EH** at any angle with **EF**.

2.—From **E** on **EH**, mark off **1, 2, 3, 4, 5,** equal spaces, any convenient length.

3.—Join **5F**, and with set-squares draw lines through **4, 3, 2, 1,** parallel with **5F** to cut **EF** in the required five equal parts.

PROBLEM 9.—To divide a straight line MN, in the same proportion as the given divided line O, 4.

1.—From **M** draw **MF** downwards, at any angle with **MN**.

2.—From **M**, on **MF**, mark off **0, 1, 2, 3, 4**—the spaces on the given divided line.

3.—Join **4N**, and with set-squares draw lines through **3, 2, 1** parallel with **4N**, cutting **MN** in the required proportional division.

NOTE.—*By this problem* **a straight line may be divided into parts having any given ratio to each other,** *as follows:—The given ratios (taken from any convenient scale), are marked off from* **M** *on* **MF**, *and parallel lines, as in the last problem, divide the given line in the ratios required.*

PROBLEM 10.—At point H in the line EF, to make angles of 60, 30, 15, 45 degrees, without set-squares.

Although pupils have been taught in the third book to make angles with set-squares, it is often necessary and frequently better to do so with the compass.

1.—With any radius from centre **H**, describe a long arc to cut **EF** in **O**.

2.—From **O** with the same radius describe another long arc to intersect the last one in **60**.

3.—From **60**, with the same radius, describe another arc to intersect the last one in **30**.

4.—Lines from **H** through these intersections give angles of **60** and **30** degrees. Bisect these angles to obtain **15** and **45** degrees.

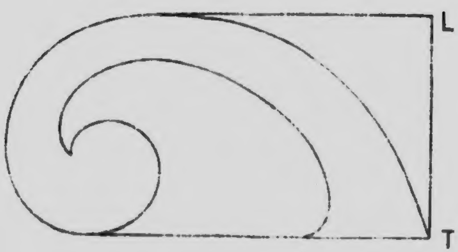
PROBLEM 11.—At point T in the line MN, make angles of 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165.

1.—With any radius, say five c.m., describe a semi-circle from **T**.

2.—This radius, five c.m., divides the semi-circle into three equal parts of **60** degrees.

3.—Proceed as in the last problem to obtain the required **12** equal angles of **15** degrees.

Great minds have wills, feeble ones have wishes.



PROBLEM 12.—To enlarge or reduce any given drawing by a series of squares. Make a copy of the given curve so that the size LT may be represented by the given line EF.

1.—Divide **LT** into any convenient number of parts, say 5 (Problem 8), on these divisions form lines of squares (using set-squares) sufficiently long to cover the given drawing. Number the lines both ways.

2.—Divide **EF** into the same number of equal parts as **LT** and on these equal divisions, draw with set-squares, a series of squares corresponding with those on **LT** and number them as before.

3.—The required drawing on **EF** may then be sketched over these squares. First notice where the curve crosses the straight lines over the example to be copied, and mark the corresponding points lightly on the lines for the drawing you are making. Sketch the curve through these points lightly at first, then finish with a firmer line as in ordinary freehand.

NOTE.—*When, instead of a line being given as* **EF** *on which the drawing is to be enlarged, it is to be copied to any size* **stated in words**, *say two and five-sevenths larger, proceed as follows:—Cover the given figure with squares, thereby enclosing it in a rectangle* **ABCD**. *Divide either side of the enclosing rectangle, say* **AB**, *into seven equal parts. On any line mark off five of these sevenths together with twice the length of* **AB**. *We then divide this length (which is of course two and five-sevenths longer than* **AB**) *into the same number of equal parts as there are squares on* **AB**, *and on these equal divisions draw a series of squares corresponding with those covering the drawing to be enlarged. The required enlargement may then be sketched as already described.*

Practice assiduously what you already know, and other things will become clear.

Ex. 8. PATTERN DRAWING.—See Example 2. In 13 of the 28 suggestions there given the construction is the same, namely, in which arcs are described from the angles and the centres of the sides of a square, equilateral triangle, or hexagon.

In some cases the arc is a semicircle or less, and in others it is even more than a three-quadrant arc. The point is, that from a geometrical aspect it is a continuous curve, and in the eventual development of the design may be either broken or interlaced.

It is quite obvious that the original figure on which the primary curve is described must be accurate, otherwise the arcs will not join tangentially without much trouble.

These designs, based on a continuous curve of arcs, may eventually be enclosed either in a circle, square, triangle or hexagon, as the case may be, and can, as in 24 and 27, be used as a diaper pattern.

Two drawings are to be made as large as the above space will admit.

He who goes the wrong road must go the journey twice over.

Ex. 9.—The square and octagon (see Example 2), form the base of 2, 5 and 25. Arcs are used, to obtain the octagon as follows:—With the corners of the square as centres and half the diagonal as radius, cut the sides of the square in the 8 corners of the octagon.

The interlaced squares, 19, may either be obtained as there shown on an outer circle, or as in the case of the triangles, 20 on inner circles. Set-squares are to be used in every possible case when constructing these patterns.

In 5 the four small squares are found from the point where the side of the octagon cuts the diagonal of the largest square. In 25 the side of the inner square on which the octagon is obtained, is taken so as to give the best effect.

Two drawings are to be m[illegible] as large as the above space will admit.

PATTERN DRAWING

To believe a business impossible is the way to make it so

Ex. 10. The ellipse and oval are frequently used in design. Figures 15, 16, 17, Example 2 show simple methods of obtaining these with the compass. For an ellipse take two equilateral triangles on a common base in the middle of the major axis, produce the sides and use the angles as centres for the four arcs. It is necessary to produce the sides, as the tangent points or junctions of the long and short arcs occur on these lines. Very fair approximations to the true curve of an ellipse are obtained in this way. By increasing the side of the equilateral triangle the ellipse becomes more flat.

The oval, 17, *which is quite a different figure from an ellipse*, is obtained by describing a circle on the minor axis, and inscribing half squares within it as shown. Produce the sides to obtain the lines of the long arcs and the radius of the small end, as in the case of the ellipse.

The drawings are to be made as large as the above space will admit.

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PATTERN DRAWING

Attempt not too hastily nor pursue too eagerly

Ex. 11. For figure 14—Example 2—describe a circle with a radius of say two and a quarter inches. Divide it into six equal parts by diameters. The radius of the interior arcs are equal to one-third of the radius of the large circle.

For 18, the diameter is divided into any *even* number of equal parts, and semicircles as shown are described on these. In addition to the artistic aspect of these interior curves, they divide the original circle into parts, equal both in area and perimeter.

For 28, one of the squares shows the construction required to obtain the forms shown in the other three. Divide the square by diagonals into right-angled triangles and inscribe four circles in these. Each of the four small circles touches two of the large ones.

Two drawings are to be made as large as the above space will admit.

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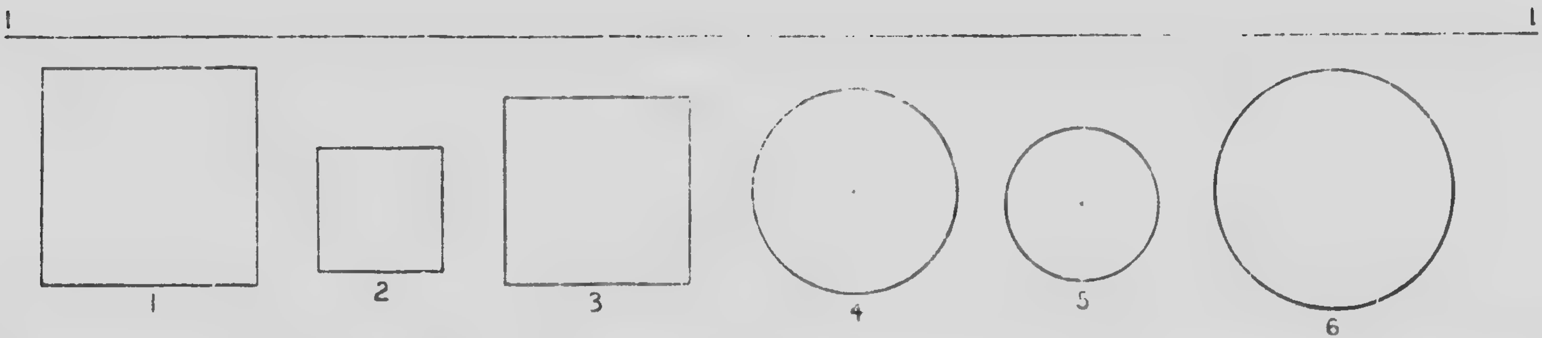
Ex. 12 Describe three circles for figure 20, see Example 2, and with the set-square of 60 draw tangents as there shown: or work from an outer circle divided into six equal parts for the angles of the triangles.

Figures 21 and 22 require very accurate work; in the former case the side of the large hexagon is divided into three and in the latter into two equal parts.

Although 23 and 26 look very different they are obtained on the same construction lines; in the former case the compass gives the form, while in the latter this is obtained by the set square of 60 degrees.

Two drawings are to be made as large as the above space will admit.

Begin nothing until you have considered how it is to be finished.



EX. 13.—FIND ELEVATIONS OF THE FOLLOWING SOLIDS FROM THE GIVEN PLANS:—

PROB. 1.—A slab 1.5 c.m. thick resting on the H.P.

PROB. 2.—A prism 4 c.m. long standing on the H.P.

PROB. 3.—A cube resting on the H.P.

PROB. 4.—A cylinder 5 c.m. high standing on the H.P.

PROB. 5.—A sphere, its centre is 3 c.m. above the H.P.

PROB. 6.—A cone 4 c.m. high its base rests on the H.P.

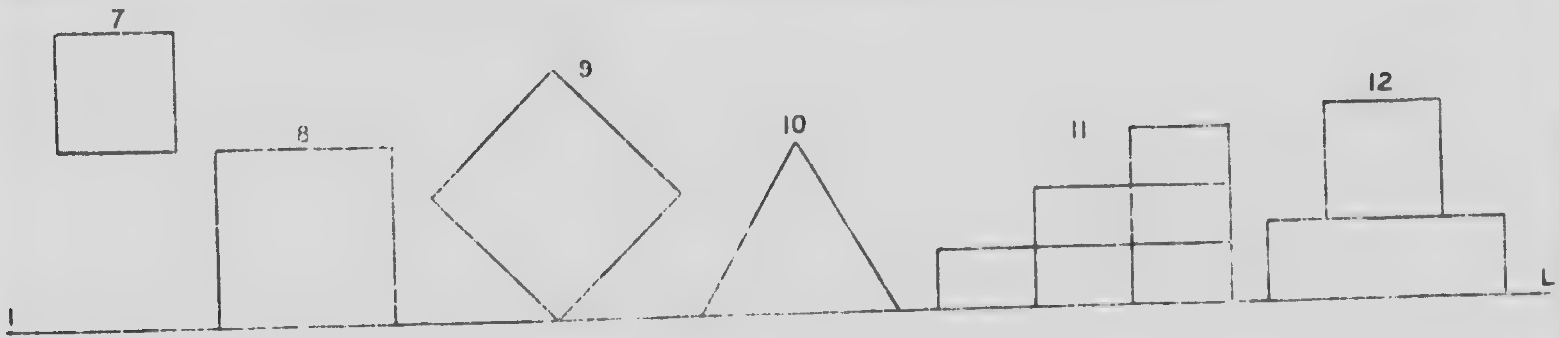
The space below the I.L. is the *horizontal plane* or H.P. The space above the I.L. is the *vertical plane* or V.P. The line I.L. is the *intersecting line*, and refers either to the V.P. or the H.P. as the case may be; thus when *elevations* or drawings are being made above the I.L. that line represents the H.P. projecting forward; when *plans* or drawings are being made below the I.L. that line represents the V.P. standing upward.

Measure the given distances above the I.L. or horizontal plane. Then draw "projectors" up from the points of the solids given on plan to obtain the elevations as shown on the small drawings.—Example 24.

Projectors are always at right angles with the intersecting line and are obtained by using set-squares.

PRACTICAL SOLID GEOMETRY

Demonstration is the best mode of instruction



Ex 14 FIND PLANS OF THE FOLLOWING SOLIDS FROM THE GIVEN ELEVATIONS:—

PROB. 7.—A square prism 2" long projecting from the V.P.

PROB. 8.—A cube, ½" from the V.P.

PROB. 9.—The same cube raised on an edge through 45 degrees.

PROB. 10.—An equilateral triangular prism 2" long and a ½" from the V.P.

PROB. 11.—Six blocks 1½" long forming steps, ¾" from the V.P.

PROB. 12.—A cube resting on the centre of a square slab. The slab is $\frac{3}{16}$" from the V.P.

Measure the given distances below the I.L., that is, from the vertical plane. Then draw projectors down from the points of the solids given in the elevation to obtain the plans as shown on the small drawings. Example 24.

Projectors are always at right angles with the intersecting line, and are obtained by using set-squares.

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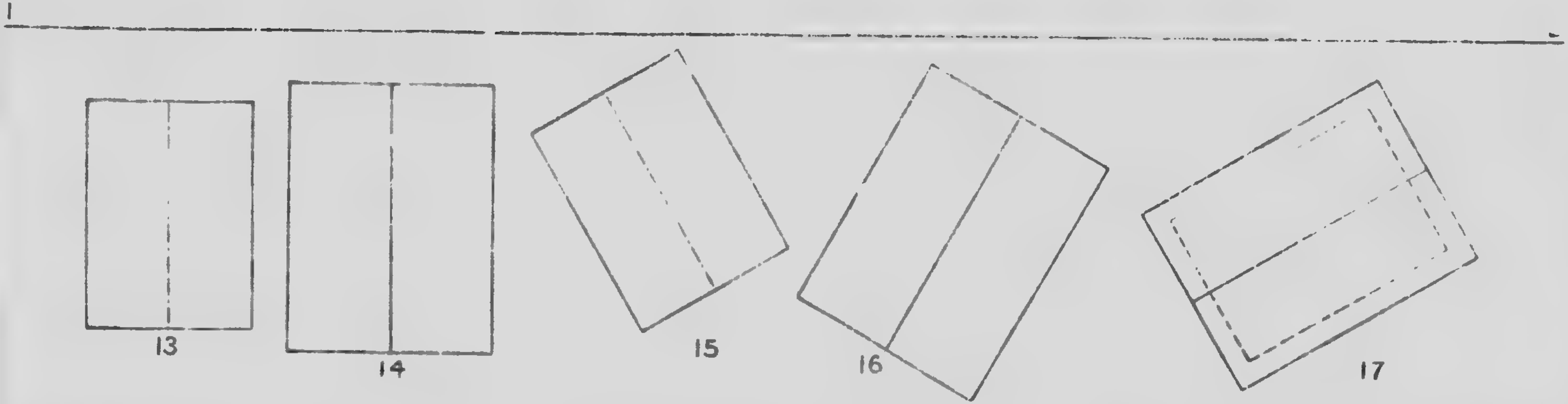


13 14 15 16 17

Ex. 15. FIND ELEVATIONS OF THE FOLLOWING SOLIDS FROM THE GIVEN PLANS.—

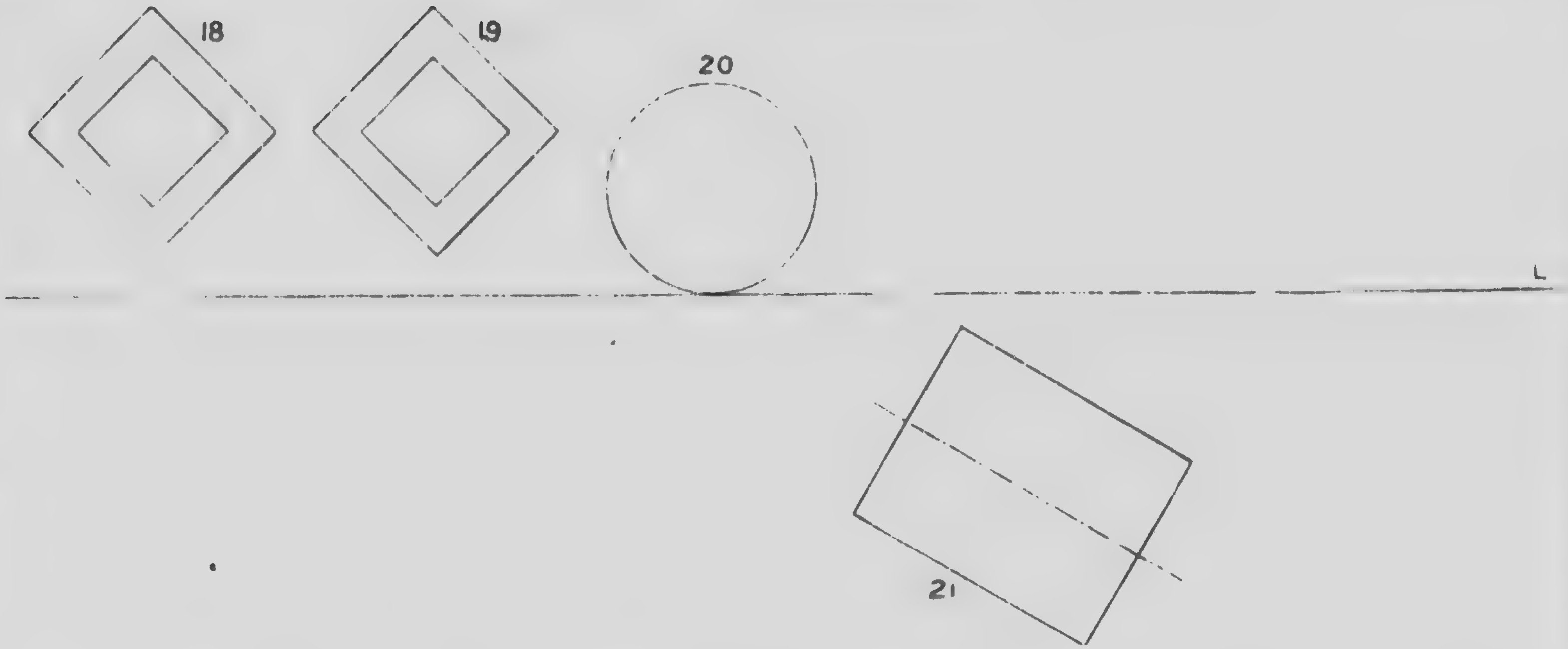
PROB. 13. A square prism resting on the H.P. *The axis is represented by the dotted line.*

PROB. 14.—An equilateral triangular prism resting on the H.P. Use a set square of 60 degrees to get the elevation, or intersecting arcs. See this problem on Example 24.

PROB. 15.—The prism of Prob. 13 turned through an angle of 30 degrees.

PROB. 16. The prism of Prob. 14 turned through an angle of 30 degrees. The height of the upper long edge may be obtained from Prob. 14. In the absence of that drawing the height or altitude of the triangular end is obtained by constructing the equilateral triangle as shown by the dotted lines Ex. 24.

PROB. 17.—The prism Prob. 14 is placed on the prism Prob. 13 so that their horizontal edges are parallel and equidistant from each other. The square prism rests on the H.P. Find the elevation of the square prism first as in Prob. 15. Proceed with the triangular prism as in Prob. 16.



FIND PLANS OF THE FOLLOWING SOLIDS FROM ELEVATIONS.

18. A square prism $1\frac{1}{2}$" long, with a square hole. The prism is $\frac{3}{4}$" from the V.P.

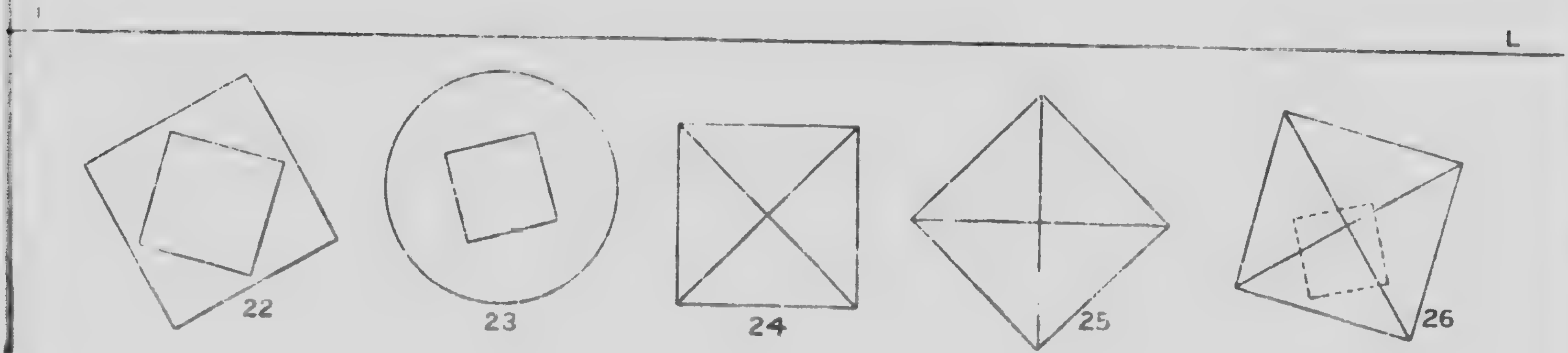
19. The large square represents a slab $\frac{3}{8}$" thick on the V.P. The small square is a prism $1\frac{1}{8}$" ... to the slab.

20. A cylinder $1\frac{3}{4}$" long, $\frac{3}{8}$" from the V.P.

21. Given the plan of the cylinder Prob. 20 when its axis (represented by the dotted line) is at an angle of 30 degrees with the V.P. Draw the elevation.

The position of the cylinder in this problem is the same as the square prism Prob. 15. Here the ends are obtained by projecting a series of points in the curve. Through these the angular view of the circle (which is an ellipse) is sketched *freehand*. See Example 24. A circle 21A, as in Prob. 20, is first described and divided into 12 equal parts as follows: Draw 4, 10 a horizontal, and 1, 7 a vertical diameter. Take the radius of the circle in the compass and from points 1, 7, 4, 10 as centres, cut the circumference in the points 2, 3, 5, 6, 8, 9, 11 and 12. Five pairs of these 12 points are horizontally and five pairs are vertically symmetrical or opposite each other. Join these symmetrical points. Mark off on the ends of the cylinder in plan the spaces between these lines, and draw projectors from them up to the V.P. to intersect the corresponding horizontal projectors from 21A. Sketch the required curve, lightly at first, through these intersections.

Fame is conferred as the recompense of labour and perseverance



Ex. 17.—Find elevations of the following solids from the given plans.

Prob. 22.—A square slab 5 m.m. thick rests on the H.P. and supports a cube.

Prob. 23.—A circular slab 12 m.m. thick rests on the H.P. and supports a square prism 45 m.m. long.

Prob. 24.—A square pyramid, axis 55 m.m. standing on the H.P.

Prob. 2[illegible].—The same pyramid with the edges of the base at 45 degrees with the V.P.

Prob. 26.—The same pyramid rests on a cube. The latter solid is on the H.P.

SCALE DRAWING

Such as boast much usually fail much.

Scale Drawing.—A scale drawing is to be made on this page from some object in the classroom or at home. The pupil is first to make a rough freehand sketch of whatever is to be drawn to scale, then measure the sizes either in metres or feet, and put these dimensions on the sketch (see Example 23).

The dimensioned sketch is either to appear on this page or is to be made on a loose sheet and gummed in beside the scale drawing for reference. The scale is to be drawn at the foot of the page so that the measurements may be verified.

Read the notes on the Cover that refer to this subject.

SCALE DRAWING

Precepts may lead, but examples draw

SCALE DRAWING.—A scale drawing is to be made on this page from some object in the classroom or at home. The pupil is first to make a rough freehand sketch of whatever is to be drawn to scale, then measure the sizes either in inches or feet, and put these dimensions on the sketch (see Example 23).

The dimensioned sketch is either to appear on this page or is to be made on a loose sheet and gummed in beside the scale drawing for reference. The scale is to be drawn at the foot of the page so that the measurements may be verified.

Read the notes on the Cover that refer to this subject.

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SCALE DRAWING

The hand of the diligent maketh rich

SCALE DRAWING. - A scale drawing is to be made on this page from some object in the classroom or at home. The pupil is first to make a rough freehand sketch of whatever is to be drawn to scale, then measure the sizes either in metres or feet and put these dimensions on the sketch (see Example 2[illegible]).

The dimensioned sketch is either to appear on this page or is to be made on a loose sheet and gummed in beside the scale drawing for reference. The scale is to be drawn at the foot of the page so that the measurements may be verified.

Read the notes on the Cover that refer to this subject.

SCALE DRAWING

Humility is the highroad to honour.

SCALE DRAWING.—A scale drawing is to be made on this page from some object in the classroom or at home. The pupil is first to make a rough freehand sketch of whatever is to be drawn to scale, then measure the sizes either in metres or feet, and put these dimensions on the sketch (see Example 23).

The dimensioned sketch is either to appear on this page or is to be made on a loose sheet and gummed in beside the scale drawing for reference. The scale is to be drawn at the foot of the page so that the measurements may be verified.

Read the notes on the Cover that refer to this subject.

Exercises in Plane Geometry.

Before beginning to draw any of these exercises the pupil should, without referring to the first page, have a clear idea of the stages of construction required for the correct solution of that exercise.

Assistance in this respect is often obtained by making small freehand sketches of the stages it is proposed to adopt—often working backwards from the result.

All working lines are to be shown.

1.—Points **A** and **B**, the extremities of an arc 7.5 c.m. radius, are 11 c.m. apart. Describe the arc and divide it into 4 equal parts.

2.—Show the largest square that can be cut out of a circle $5\frac{5}{8}$" diameter.

3.—A straight line **AB** is 11 c.m. long. Find **C**, a point 3.5 c.m. distant from this line, and equidistant from its extremities. Join **C** with **A** and **B** and give the name of the figure so formed.

4.—Points **A** and **B** are $1\frac{3}{4}$" apart. **C** is $2\frac{3}{4}$" distant from **A** and **B**. Join **CA** and **CB**, and make an angle $3\frac{1}{4}$ times greater than the angle **ACB**.

5.—The base **AB** of a triangle is 7 c.m. long; the angle at **A** is 30 degrees, that at **B** is 105 degrees. Construct the triangle; give its name; show its altitude and write the size of the angle at the apex.

6.—Draw a line **AB**, $3\frac{1}{4}$" long and find point **C** on it so that **AC** shall be two-sevenths of **AB**.

7.—Make drawings of your set-squares when the longest side of each is 13 c.m.

8.—Divide a circle $3\frac{1}{8}$" diameter into 3 equal parts by lines drawn from its centre. Give the size of the angles formed by the radii.

9.—Describe an arc **AB** with a radius of 9 c.m., so that the steel point of the compass will not make a mark on the paper (put the steel point on a set-square when describing the arc). Find a point on the paper so that an arc described from it shall be parallel with and 5 m.m. distant from **AB**.

10.—At points **A** and **B** the extremities of a line $1\frac{7}{8}$" long construct angles of 90 and 45 degrees forming a triangle **ABC**. Complete the square of which this triangle is one-eighth.

11.—A ladder 10 feet long leaning against a vertical wall makes an angle of 75 degrees with the ground which is horizontal. Draw three lines for the ladder, wall and ground, when a foot is represented by a quarter of an inch. Give the angle the ladder makes with the wall.

12.—On a straight line **AB**, 9 c.m. long find point **X** so that **AX** shall be three-fifths of **XB**.

13.—Points **A** and **B** are $2\frac{3}{4}$" apart. Find a point **C** so that lines from **A** and **B** will form four equal angles at that point.

14.—Draw **AB** a straight line 9.5 c.m long. **C** is 4.5 c.m. from **A** and 6.5 c.m. from **B**. Through **A** draw a line parallel with **CB**, and through **B** a line parallel with **AC** producing them to meet at **X**. What is the name of the figure **ACBX**?

15.—Draw any scalene triangle and describe a circle to pass through the three angular points.

16.—Take any three points **A**, **B** and **C** not in a straight line. Join **AB** and draw a line from **C** to meet **AB** in an angle of 45 degrees.

17.—The centre lines of four straight roads meet at point **X**. Two of these **AX** and **BX** are at right angles. **CX** makes 120 degrees with **BX**, and **DX** lies half way between **CX** and **AX**. The roads **DX** and **BX** are each 2 chains wide, the other two are half that width. Show these to a scale of 1 inch to a chain.

18.—Points **A** and **B** are 5 c.m. apart. **C** is 3·5 c.m. from **B** and 5·5 c.m. from **A**. Find a point **D** equidistant from **A**, **B** and **C**.

19.—Construct a quadrant when the extremities of the arc are $3\frac{3}{8}$" apart. Divide the quadrant into six equal parts.

20.—How would you prove by a simple experiment that the three angles of any triangle contain 180 degrees or two right angles, and that the four angles of any quadrangular figure contain 360 degrees or four right angles?

Exercises in Solid Geometry.

For each of the 26 problems in this book a drawing of the solid is given on one plane of projection, and the pupil is required to represent it on the other plane.

For the following 20 exercises no drawings are shown. Descriptions or specifications of the surfaces or solids and their relations to both planes of projection are given from which plans and elevations are to be made.

Exercises 1 to 10 are on lines and surfaces in simple positions such as are found in the plans and elevations on page 24.

Exercises 11 to 20 are on solids, different in size and position from those on page 24.

Before beginning to draw an exercise the pupil should have a clear idea, not only of the surface or solid to be represented, but its position with reference to both the planes of projection. Small models will be of great assistance in this respect, but if with these there is still any difficulty, reference may be made to the problem on which the exercise is based. These problems should, however, be referred to after and not before the required exercises are done.

1.—A point **A** is 2" above the H.P. and 1" from the V.P. (such as the apex of cone, Prob. 6).

2.—A line $2\frac{1}{2}$" long stands vertically on the H.P.; it is $1\frac{1}{4}$" from the V.P. (such as the axis of cylinder, Prob. 4).

3.—The same line projects from, and is at right angles with the V.P. It is $1\frac{1}{4}$" above the H.P. (axis of prism, Prob. 7).

4.—A line 5 c.m. long is parallel with both the V.P. and the H.P. It is 3.5 c.m. from the V.P. and 6 c.m. above the H.P. (an edge of the cube, Prob. 3).

5.—Draw a line 3.5 c.m. long on the H.P. It is 1.5 c.m. from, and parallel with the V.P. This line is the plan of a square surface, one edge of which is on the H.P. (as the near face of the solid, Probs. 3 and 13).

6.—Draw in elevation a $1\frac{1}{2}$" line $2\frac{1}{2}$" above and parallel with the H.P. This line represents a square surface when its edge nearest the V.P. is $1\frac{1}{2}$" from and parallel with it (the upper face of cube, Prob. 8 or 12).

7.—The same square surface rests on the H.P. on an edge at right angles with the V.P. There is $\frac{1}{2}$" between the V.P. and the square (the side faces of cube, Prob. 3).

8.—An equilateral triangular surface of 5.5 c.m. edge is parallel with and 1.5 c.m. from the V.P. An edge of the triangle is on the H.P. (the ends of prism, Prob. 14).

9.—A plan of the last surface is represented on the H.P. by a line at an angle of 45 degrees with the V.P. An edge of the triangle is on the H.P. (the ends of prism, Prob. 16).

10.—The same surface is parallel with the H.P. and 1.8 c.m. above it. A corner of the triangle is on the V.P. and an edge of the surface is at 75 degrees with that plane. (From any point on the I.L. draw a line 5.5 c.m long and at 75 degrees with it. This is one side of the triangle in plan).

11.—A cone, axis 3", base 2" rests on its apex on the H.P. The axis is vertical and $2\frac{1}{2}$" from the V.P. (Prob. 6).

12.—The centre of a sphere 3 c.m. diameter is 5.7 c.m. above the H.P. and 4.3 c.m. from the V.P. (Prob. 5).

13.—A 5 c.m. square prism 7.2 c.m. long projects from the V.P. The axis is 6.4 c.m. above the H.P. and its rectangular faces are parallel and perpendicular with the H.P. (Prob. 7).

14.—A 2" cube rests on the H.P. on a face. A vertical edge is on the V.P., and the vertical faces of the solid are at 45 degrees with that plane. (Prob. 9 is here transposed. Draw the plan first).

15.—A prism 3.8 c.m. square by 6.5 c.m. axis, rests on the H.P. on a rectangular face. The axis is at 45 degrees with the V.P. (Prob. 15).

16.—A slab $1\frac{1}{2}$" square by $\frac{1}{2}$" thick rests on the H.P. on a square face. The solid is $\frac{1}{4}$" distant from and parallel with the V.P. A pyramid—base 1" square, axis 2"—rests on the slab; the edges of the base of the former being parallel and equidistant from the edges of the slab. (Prob. 12).

17.—An equilateral triangular prism, 3.7 c.m. edge of end by 7.3 c.m. axis, has one long edge on the H.P. and one of its rectangular faces vertical. The end of the solid is parallel with and .5 c.m. from the V.P. In this exercise the elevation, which is drawn first, has a side (rectangular face) at 90 degrees with the I.L. instead of horizontal as in Prob. 14.

18.—An inch square prism 3" long stands on the H.P. The axis is vertical and 2" from the V.P.; the rectangular faces of the solid are at 60 and 30 degrees with the V.P. (a position somewhat similar in Prob. 23).

19.—An equilateral triangular prism, 4.2 c.m. edge of end by 7.5 c.m. axis, has one long edge on the H.P. The axis is at 45 degrees with the V.P. and one of its rectangular faces is parallel with the H.P. (The prism of Prob. 16 is here turned upside down).

20.—A cone—base 5 c.m. axis 8 c.m.—rests on the H.P. on one point of the base. The axis is horizontal and inclined at 45 degrees with the V.P. First draw the plan—an isosceles triangle, base 5 c.m., altitude 8 c.m., the base being at 45 degrees with the I.L. Project the base as in Prob. 21.

SCALE DRAWING

Labour brings pleasure—idleness, pain.

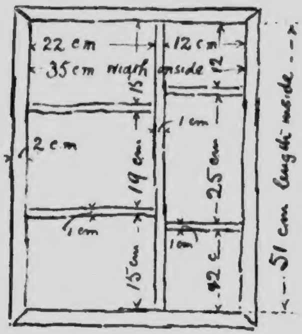

Fig. 1 Work-box

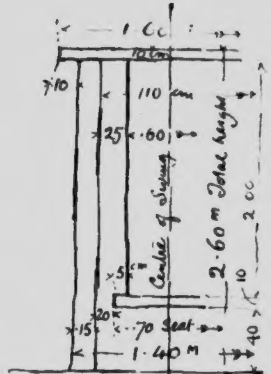

Fig. 2 Swing.

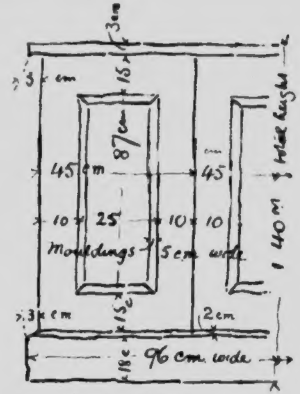

Fig. 3 Cupboard.

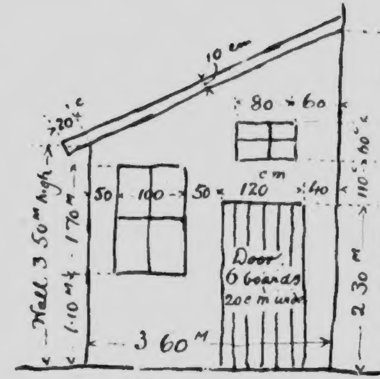

Fig. 4 Shed

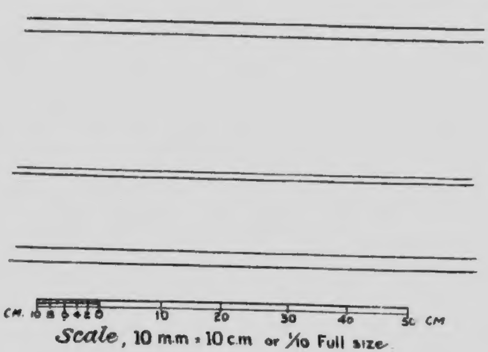

Fig. 5.

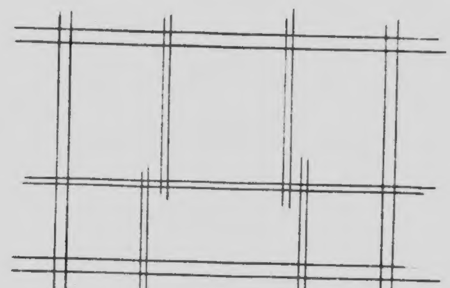

Fig. 6

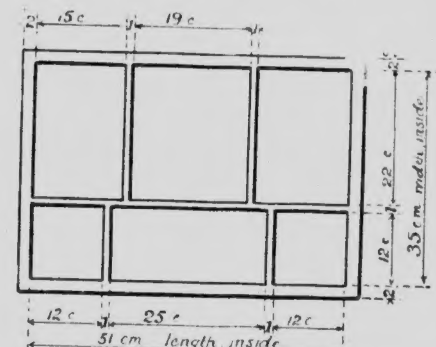

Fig. 7.

SCALE DRAWING.—Figs. 1 to 4 show freehand sketch work, dimensioned for scale drawing. Such sketches need not be in accurate proportion, but the arrowheads for their dimensions must indicate clearly the spaces or distances to which each dimension belongs.

Scale drawings are not to be made from the above sketches. Select a simple object and make a freehand dimensioned sketch of it, then from this sketch draw the object to scale on one of the blank pages—18-21.

Figs. 5 to 7 show how a scale drawing of the workbox or other simple object is commenced and finished.

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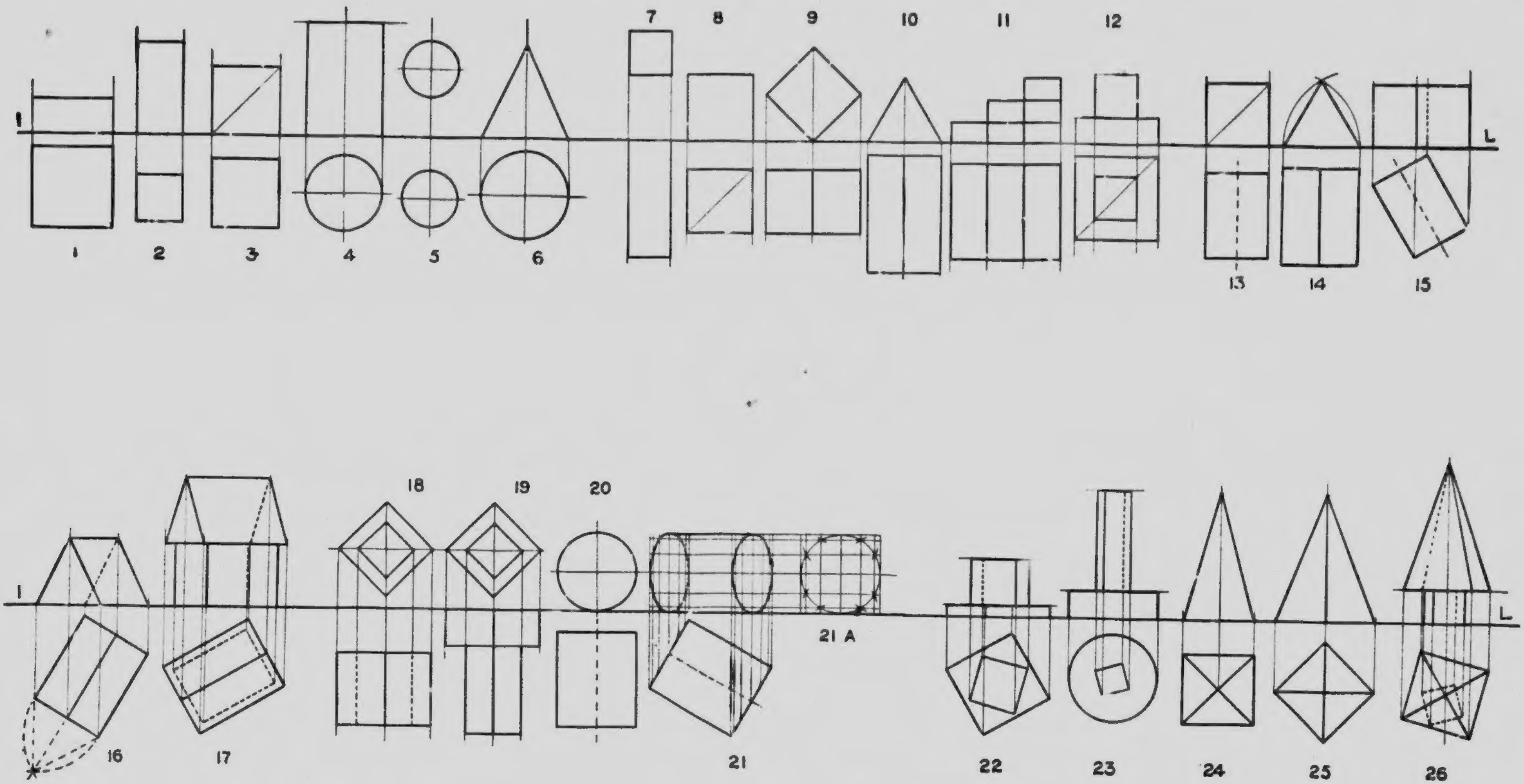
PRACTICAL SOLID GEOMETRY

Time, patience, and industry, are the three great masters of the world.



PROBLEMS IN SOLID GEOMETRY.—The above drawings show the lines necessary to obtain elevations and plans as required by Examples 13 to 17 in this book. *They are not given to copy from.* The pupil should make the required drawing first, and then refer to the solution here in order to verify the result. Those pupils, however, who may be working alone and are unable to proceed with any part of the work may first consult these small drawings.

All working lines must be shown.

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To illustrate the principles of the subject, drawings of the planes of projection are shown in Book V—A, Ex. 2. They are given there owing to want of space in this book.

It is important that pupils have a clear knowledge regarding the character of the six groups of solids used in the course, namely:—Sphere, cylinder, cone, cube, prism and pyramid, and that they shall be able to describe definitely each of these. The only way to arrive at this result is to bring them into actual contact with the solids.

In all cases set-squares are to be used to obtain parallel and perpendicular lines.

SCALE DRAWING. This work is to be done from actual objects. First a freehand sketch is made, and the sizes of the different parts of the object are measured and marked on the sketch; then from this freehand dimensioned sketch a scale drawing of the object is made—set-squares being used as in Solid Geometry.

For alternate Scale Drawings the English foot and the French metre are to be used.

To find the scale to which any drawing may be made, such as a table 3′ 9″ long by 2′ 6″ high. The drawing is to fairly fill a page of this book, which is about 10″ by 8″. *The representative fraction* of the scale is first determined. This fraction expresses the actual relation as regards size between the object and the required drawing, and is found by dividing the length of the object by the distance this length is to occupy on the paper. The latter distance should be such as will divide the former without a remainder. To arrive at this it is sometimes necessary to suppose the object a little longer or shorter so as to get the required division—there should always be sufficient length of paper to come and go on; thus, the table is 3′ 9″ or 45″ long. Suppose the drawing is to be 8″ long, increase the 45″ to 48″, then dividing 48″ by 8″ we get 6, or a representative fraction of $\frac{1}{6}$ full size for the required drawing.

To construct a scale to represent a given fraction—take any unit from a full size measure of inches or centimetres and divide it into the number of parts indicated by the denominator of the representative fraction. Each of these divisions will represent the corresponding unit of the required scale. The drawing of the table is to be $\frac{1}{6}$ full size—draw a line and mark off spaces of 2″ to represent feet, because 2″ is one-sixth of one foot. The end space of 2″ is divided into 12 equal parts, each of which will of course represent an inch.

All the parts of a Scale Drawing are to be coloured, and the tints so varied as to bring out prominently the different parts of the object.

All the dimensions used in making a Scale Drawing are to be put on it as in former *working drawings*, clearly arranged, and to interfere as little as possible with the lines of the object. They are to be drawn in with care so that 3's may not be mistaken for 5's or 8's, and 4's for 7's.

PATTERN DRAWING. The small drawings, Example 2, are given as suggestions with regard to the design work required on the five blank pages for Examples 8 to 12. The pupil is to study the construction lines and select a triangle, quadrangle, hexagon or octagon, within which *an original design is to be worked out*. After a little attentive study it will be seen that the construction of these patterns is exceedingly simple, and although the work is to a certain extent manual it is mainly inventive.

Two drawings are to be made on each page; they are to be as large as the available space will admit, and are to err on the side of simplicity rather than complexity. The pupil will find explanatory notes regarding these figures on the pages devoted to this work. Set-squares are to be used in all cases.

These drawings are to be coloured throughout, and in addition to the geometrical division of the space, natural history, or other units may be arranged within these where the pattern is simple.